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Styret for det industrielle rettsvern

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993116 Tegningsfigur som ønskes publisert sammen med sammendrag	Fig. 1

Deep water TLP Tether System

This invention relates to the art of offshore structures and, more particularly, to tension leg platforms (TLP) for exploitation of deep sea hydrocarbon reserves .

Mooring elements, or tethers on tension leg platforms are anchored to the seabed. They usually consist of steel pipes and are kept in tension by the buoyancy of the platform.

With the gradual depletion of onshore and shallow subsea subterranean hydrocarbon reservoirs, the search for additional petroleum reserves is being extended into deeper and deeper waters. As such deeper reservoirs are discovered, increasingly complex and sophisticated production systems are being developed. It is projected that soon, offshore exploration and production facilities will be required for probing depths of 1500m or more.

One way of reaching these depths is by using tension leg platforms. A TLP comprises a semi-submersible-type floating platform anchored to foundations on the sea bed through members or mooring lines called tension legs or tethers. The tension legs are maintained in tension at all times by ensuring that the buoyancy of the TLP exceeds its operating weight under all environmental conditions. The TLP is compliantly restrained by this mooring system against lateral offset allowing limited surge, sway and yaw. Motions in the vertical direction of heave, pitch and roll are stiffly restrained by the tension legs.

External flotation systems can be attached to the legs but their long-term reliability is questionable. Furthermore, added buoyancy of this type causes an increase in the hydrodynamic forces on the leg structure.

TLPs' based on today's technology are considered competitive down to 1,000-1,500m. Beyond this depth, the tether system becomes increasingly heavy, requiring an increased platform size to carry the tether weight. This results in a larger platform, which has a significant impact on the overall cost.

For a TLP at 3,000m, a conventional tether system (one thickness, one diameter) represent a weight almost equal to the payload. In previous designs, it has been have proposed to reduce the wall thickness at the top to reduce the weight penalty.

A solution to avoid these disadvantages related to the TLP, is to modify the tether system to reduce the need for increased hull size. The industry has devoted a considerable effort to develop tether systems based on various designs. Filling tether pipes with low density material, pressurising the interior to increase the hydrostatic capacity and replacing the steel tether pipes by composites are examples of these efforts..

Another solutions can be found in NO 1997 3044; showing a design used for depths down to 700 m, built by pipe sections with a diameter between 0,5 to 1,2 m. The overall buoyancy of the tension leg is meant to be more or less neutral. This is achieved by adding an additional floating body at the top of the pipe.

NO 1997 3045 shows a welding connection on a tension leg. The publication shows two pipes of different diameter and wall thickness' welded together.

The object of the present invention is to overcome the above mentioned deficiencies and to design tethers for TLP's that reduces the necessary added payload on the platform by the as a result of the tether weight. This object is achieved by a TLP as defined in the appending claims.

The invention relates to a tether system for TLP's, with tethers having upper and lower pipe sections, the tethers having a reduction of the diameter towards the seabed.
The invention is a concept for modifying today's technology for use in ultra deep waters. By introducing reductions in the tether diameter, the lower sections of the tether towards the sea bed will normally be negatively buoyant because of the considerable wall thickness necessary to withstand the hydrostatic pressure. The upper sections can more easily be made buoyant as the hydrostatic pressure is less at the top. This will help to balance the overall weight of the upper and lower sections.

The tether pipes are dimensioned to carry the tension from a platform consisting of a nominal pre-tension plus the tension variation by functional and environmental loads. The pipes are kept empty, to reduce the weight/increase buoyancy . The pipes must not only be designed to withstand the loads applied by the platform, but also has to resist the hy-

drostatic pressure from the surrounding sea. This becomes more prominent as the depth/-hydrostatic pressure increases. At great depths (in the order of 1,000m) the pipes can no longer be designed to have a neutral buoyancy (a diameter to thickness ratio of about 30). In order to withstand the pressure, the diameter to thickness ratio has to be reduced, which results in added load on the platform.

The thickness of each section is sized according to capacity. It should also be considered that the tether vertical stiffness is critical for performance, and it is therefore favourable to maintain a fairly equal stiffness/length of each section.

The reduction of overall diameter will typically be made in steps, with intersections between the steps. The number of steps will depend on the length of the tether/depth of which it is to be used etc.
In-between each diameter, a transition piece carries the load. This is a well proven detail from previous TLP applications.

The tethers may have a gradual transition between the upper and lower sections instead of the above described steps, but such tethers are less likely to be used as such tethers probably will require a more complex manufacturing process.

With near neutral tethers, the reduction of the hull weight is in the order of 30 percent as compared the hull weight when tethers according to prior art are used. This is due to the decrease of added payload when tethers of the invention are used.

The invention will now be explained in more detail, with reference to the drawings in which

Figure 1 shows a tension leg platform with tethers according to the present invention;
Figure A1 shows the tension distribution of the two concepts;
Figure 2 shows a tether string according to the invention;
Figure 3 shows a cross section of a diameter transition section; and
Figure 4 shows an optimisation chart where a tethers outer diameter and the wall thickness are plotted to show how buoyancy, stiffness and hydrostatic capacity varies.

The following gives an embodiment by way of the following non-limiting example.

A TLP (4) with one step and two tethers (6) having two diameters holding the platform is shown on Fig 1. A transition piece (3) between the diameters is shown Fig 3 in detail. An upper part of a tether (1) may then have a diameter of 142 mm and a wall thickness of 24.5 mm, whereas the lower part (2) has an outer diameter of 76 mm and a wall thickness of 42 mm. The tethers are anchored to foundations (5).

A tether with two steps is shown on Fig 2.

Samples of further variations in loads, dimensions and configurations are illustrated in Table 1. The embodiments suggests a wellhead platform in West African environment. The deck weight includes the facilities, the structural steel and the operational loads, including the riser tensions. The riser tensions are increased with the water depth. The hull and displacement are increased to carry the deck load and the tether pretension.

The thick tether system represents the conventional one thickness tether, which has to have a large thickness to diameter ratio, to withstand the hydrostatic pressure at the bottom. The stepped tether system represents the invention, which allows for reduction of the tether pretension. This allows for reduction of the displacement and of the hull weight.

Table 1 West Africa TLP Application

WATER DEPTH	(m)	1000m	1500m		2000m		3000m		
TETHER SYSTEM	(-)	THICK	THICK	STEPPED	THICK	STEPPED	THICK	STEPPED	MAX. STEP
DECK WEIGHT	(t)	4,800	5,000	5,000	5,300	5,300	5,900	5,900	5,900
RISER TENSION	(t)	2,800	4,200	4,200	5,600	5,600	8,400	8,400	8,400
HULL & BALLAST	(t)	5,300	6,000	5,800	7,100	6,400	10,100	8,200	7,700
TETHER PRETENSION	(t)	2,400	3,300	2,600	5,500	3,000	13,000	6,200	4,500
DISPLACEMENT		**15,300**	**18,500**	**17,600**	**23,500**	**20,300**	**37,400**	**28,700**	**26,500**

TETHERS									
NO. OF DIAMETERS		1	1	2	1	2	1	5	10
DIAMETER (top/bott.)	Inch	26	30	46/24	32	52/28	34	56/30	56/30
DIAMETER (top/bott.)	mm	66	76	117/61	81	132/71	86	142/76	142/76
THICKNESS (top/bott)	mm	22.2	28.5	38.5/23	35.5	34.5/31	47.5	24.5/42	24.5/42
MAX. LOAD - TOP	(kN)	7,200	8,900	8,100	12,400	8,000	24,000	14,700	12,600
WEIGHT in WATER	(t)	0	70	-10	300	20	1,100	300	70

The above described embodiments use steel as the construction material, but the invention is also meant to cover other materials such as composites.

Claims:

1. Tether system for tension leg platforms (4), characterised by tethers (6) having upper and lower pipe sections (1, 2), the tethers (6) having a stepped reduction of the diameter towards the seabed.

2. Tether system for tension leg platforms (4) according to claim 1, characterised by having tethers (6) with an increasing pressure resistance as the depth towards the sea-bed increases.

3. Tether system for tension leg platforms, characterised by tethers (6) having pipes of different diameter, with a substantially continuos reduction towards the seabed, and an increased pressure resistance towards the sea-bed.

4. Tether system for tension leg platforms (4) according to claim 1, characterised by tethers having pipes with at least two stepped reductions of the diameter towards the seabed.

5. Tether system for tension leg platforms (4) according to claim 1, characterised by tethers having pipes with at least two stepped increases of the wall thickness towards the seabed.

6. Tether system for tension leg platforms (4) in accordance with claim 1 or 3, characterised by having upper section(s) (1) with positive buoyancy, to make the upper section(s) (1) compensate for the weight in water of the lower section(s) (2), thereby resulting in a tether that has a weight in water close to neutral.

7. Tether system for tension leg platforms (4) in accordance with claim 1 or 3, characterised by having upper sections (1) with reduced wall thickness such that the total cross sectional area of the steel is maintained approximately constant over the height.

8. Tether system for tension leg platforms (4) in accordance with claim 1 or 3, c h a r a c t e r i s e d b y having sections made of steel.

9. Tether system for tension leg platforms (4) in accordance with claim no.1 or 3, c h a r a c t e r i s e d b y having sections made of composite materials.

10. Tethers (6) for deep sea use, c h a r a c t e r i s e d b y having pipes with a stepped reduction of the diameter towards the seabed.

11. Tethers (6) for deep sea use according to claim 10, c h a r a c t e r i s e d b y using the tethers on tension leg platforms

12. Tethers (6) for deep sea use, c h a r a c t e r i s e d b y having decreasing buoyancy towards the seabed

Summary

The invention proposes to increase the diameter of the top sections (2) of the tethers on tension leg platforms (TLP) (4) to the make top sections (1) positively buoyant. This buoyancy can be designed to compensate for the weight of the lower sections (2) to make the total buoyancy of the tether closer to neutral. The selection process for each section is driven by requirements for buoyancy, stiffness and external pressure resistance.

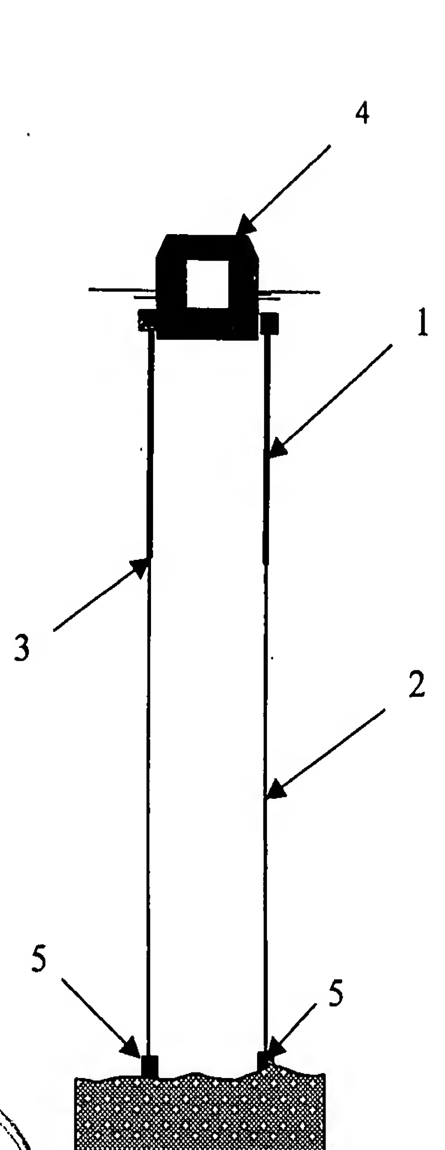


Figure 1:
TLP with tethers

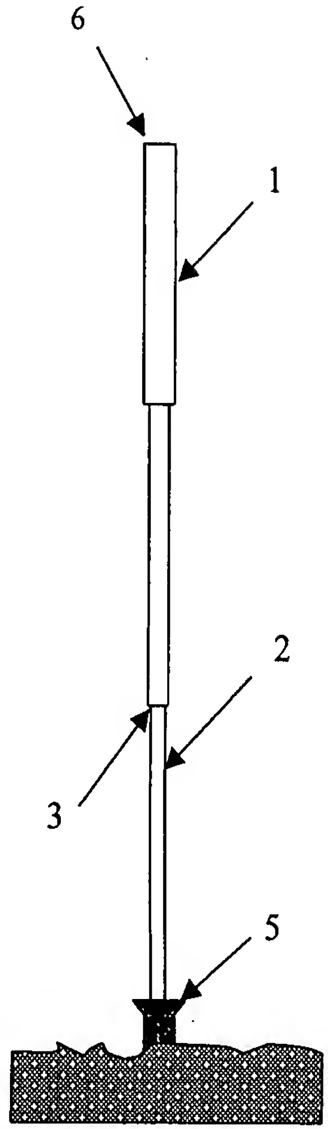


Figure 2:
Tether string

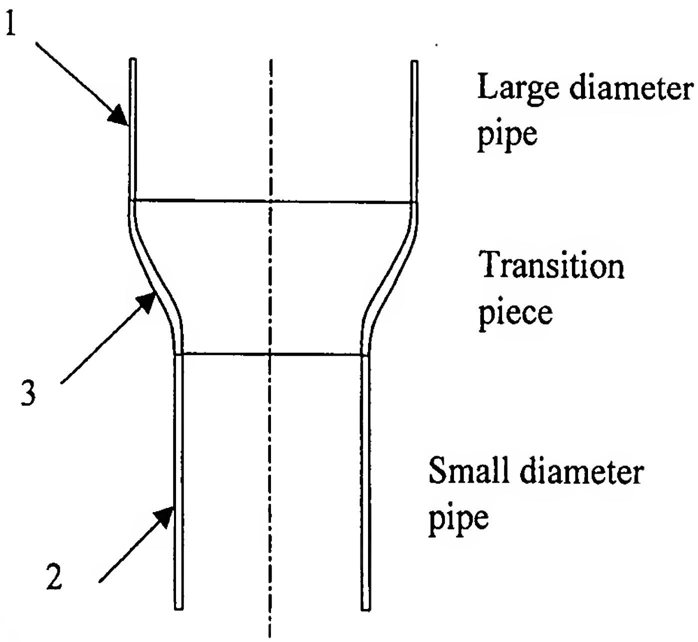


Figure 3:
Diameter transition

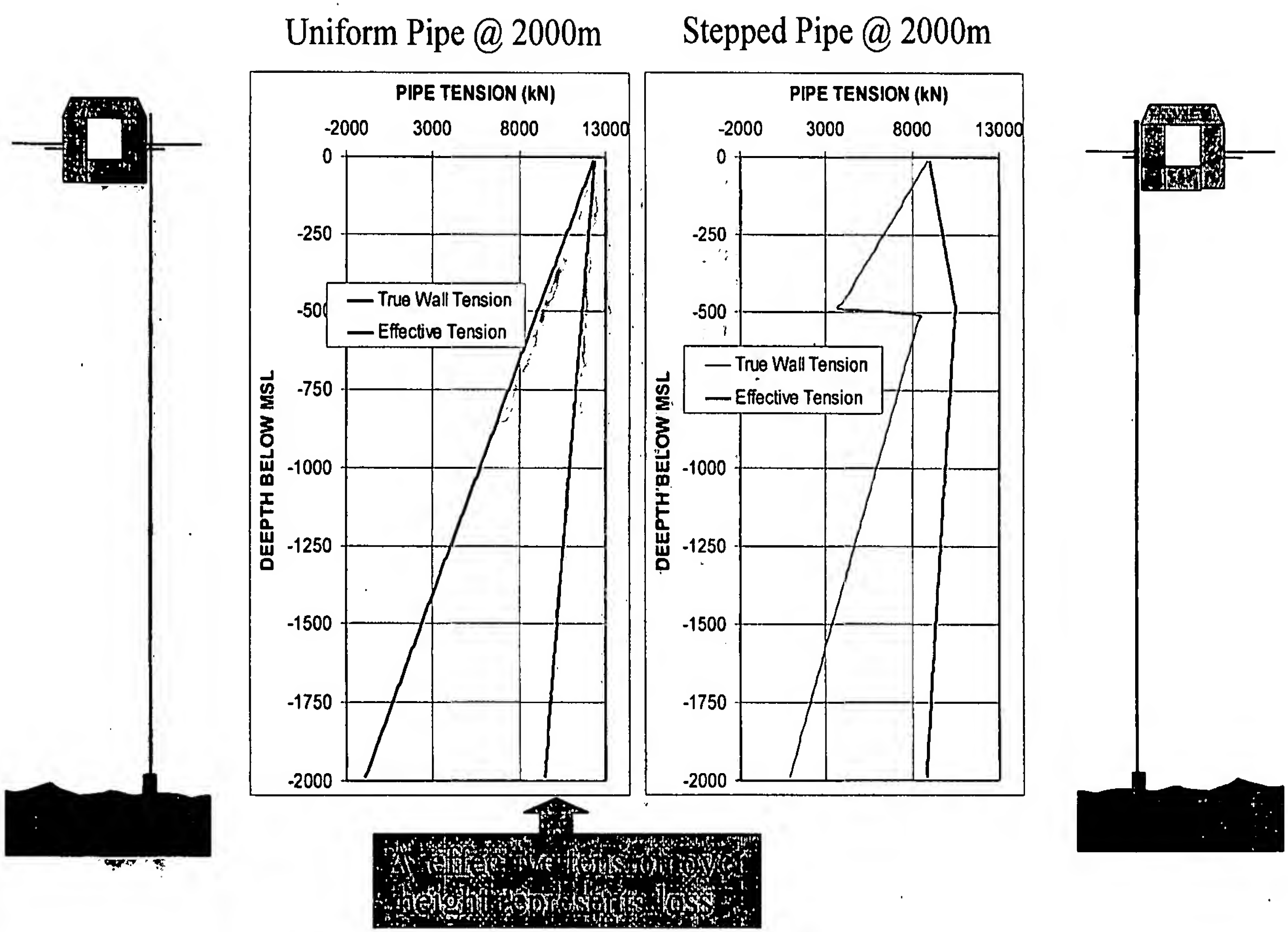
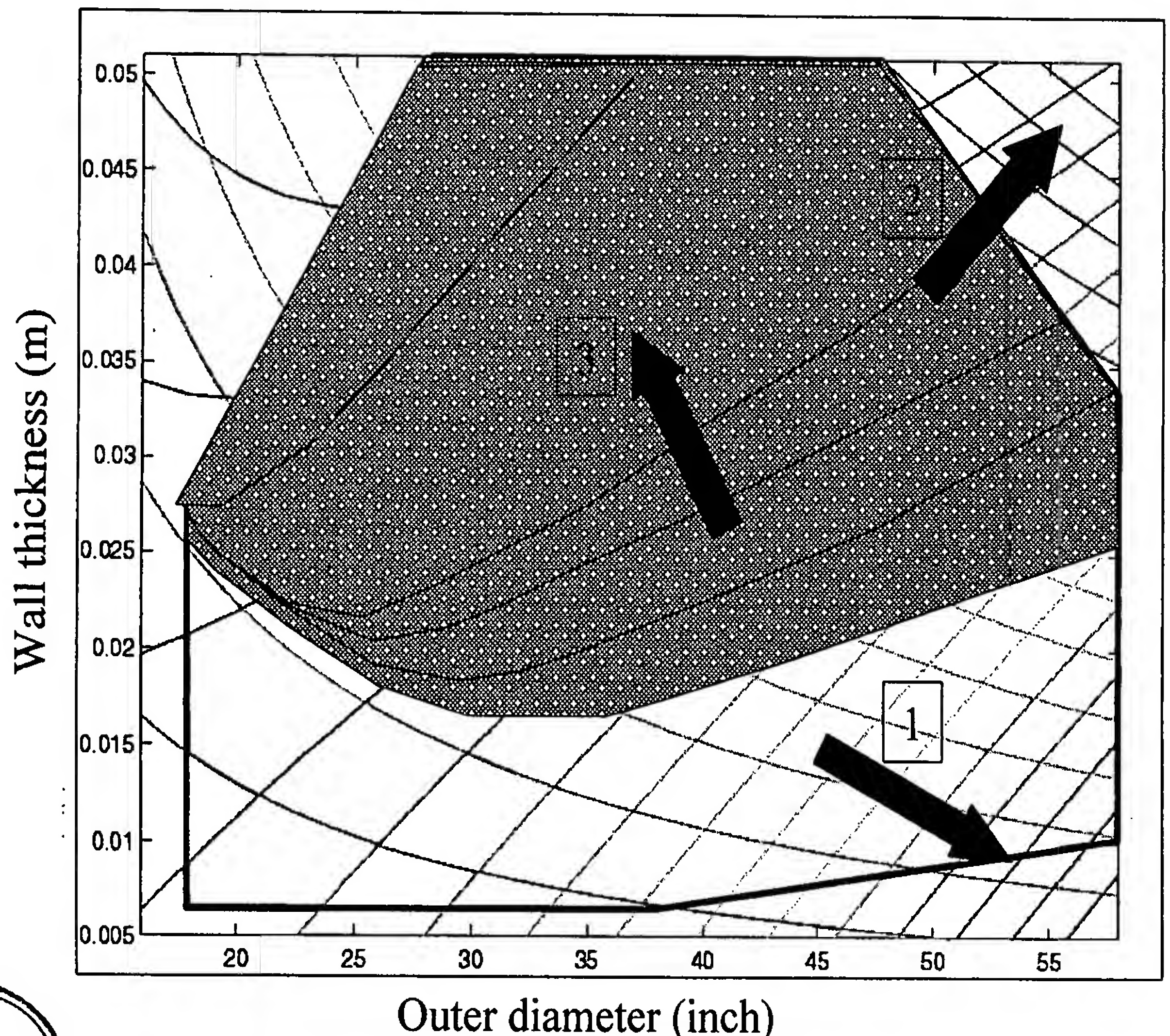


Figure A1 Tether Pipe Tension



Optimisation

1. Direction of increased buoyancy
2. Direction of increased stiffness
3. Direction of increased hydrostatic capacity

Figure 4: Optimisation chart